CHAPTER 2

TECHNICAL SKETCHING

When you have read and understood this chapter, you should be able to answer the following learning objectives:

- *Describe the instruments used in technical sketching.*
- *Describe the types of lines used in technical sketching.*
- *Explain basic computer-aided drafting (CAD).*
- *Explain computer numerical control (CNC) design techniques used in machining.*

The ability to make quick, accurate sketches is a valuable advantage that helps you convey technical information or ideas to others. A sketch may be of an object, an idea of something you are thinking about, or a combination of both. Most of us think of a sketch as a freehand drawing, which is not always the case. You may sketch on graph paper to take advantage of the lined squares, or you may sketch on plain paper with or without the help of drawing instruments.

There is no MIL-STD for technical sketching. You may draw pictorial sketches that look like the object, or you may make an orthographic sketch showing different views, which we will cover in following chapters.

In this chapter, we will discuss the basics of freehand sketching and lettering, drafting, and computer aided drafting (CAD). We will also explain how CAD works with the newer computer numerical control (CNC) systems used in machining.

SKETCHING INSTRUMENTS

Freehand sketching requires few tools. If you have a pencil and a scrap piece of paper handy, you are ready to begin. However, technical sketching usually calls for instruments that are a little more specialized, and we will discuss some of the more common ones in the following paragraphs.

PENCILS AND LEADS

There are two types of pencils (fig. 2-1), those with conventional wood bonded cases known as wooden pencils and those with metal or plastic cases known as mechanical pencils. With the mechanical pencil, the lead is ejected to the desired length of projection from the clamping chuck.

There are a number of different drawing media and types of reproduction and they require different kinds of pencil leads. Pencil manufacturers market three types that are used to prepare engineering drawings; graphite, plastic, and plastic-graphite.

Graphite lead is the conventional type we have used for years. It is made of graphite, clay, and resin and it is available in a variety of grades or hardness. The harder grades are 9H, 8H, 7H and 6H. The medium grades are 5H, 4H, 3H, and 2H. The medium soft grades are H and F. The soft grades are HB, B, and 2B; and the very soft grades are 6B, 5B, 4B, and 3B. The latter grade is not recommended for drafting. The selection of the grade of lead is important. A harder lead might penetrate the drawing, while a softer lead may smear.

Plastic and graphite-plastic leads were developed as a result of the introduction of film as a drawing medium, and they should be used only on film. Plastic lead has good microform reproduction characteristics, but it is seldom used since plastic-graphite lead was developed. A limited number of grades are available in these leads, and they do not correspond to the grades used for graphite lead.

Plastic-graphite lead erases well, does not smear readily, and produces a good opaque line suitable for

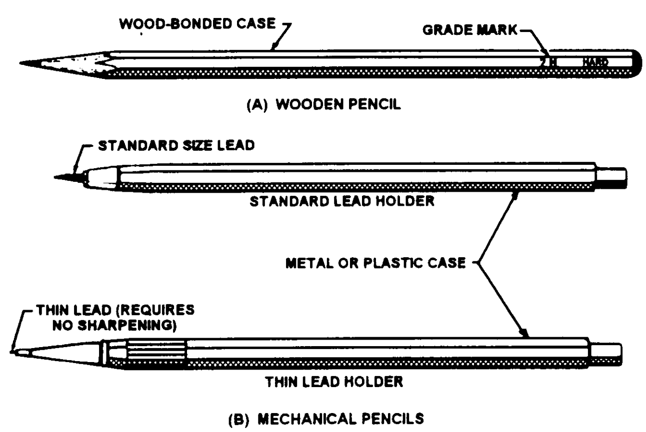


Figure 2-1.—Types of pencils.

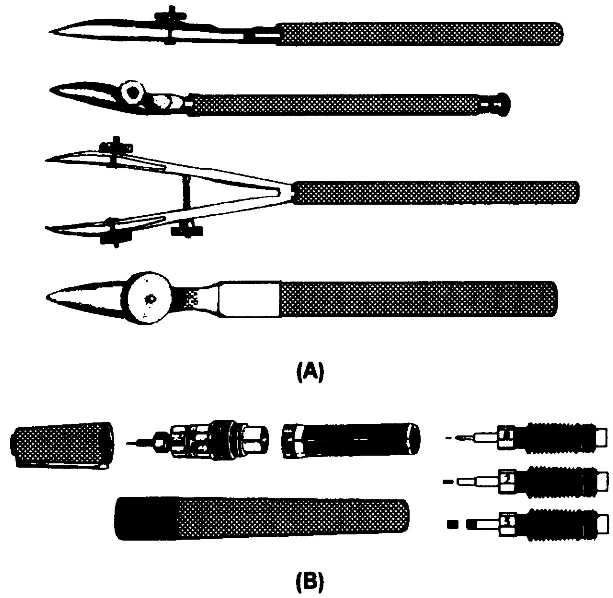


Figure 2-2—Types of pens.

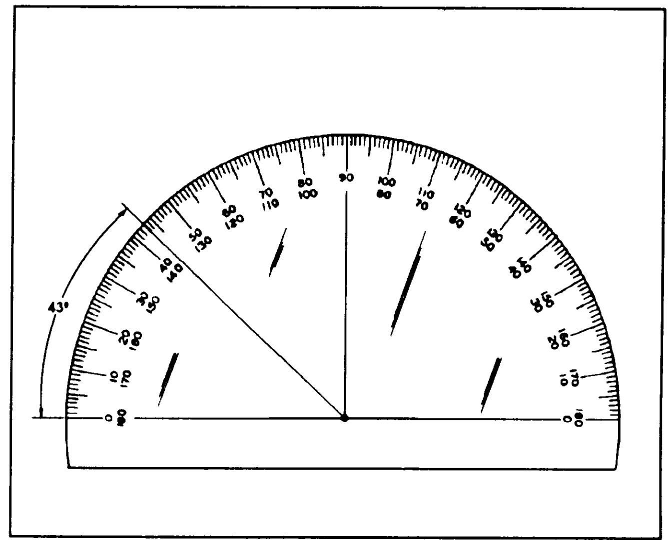


Figure 2-3.—Protractor.

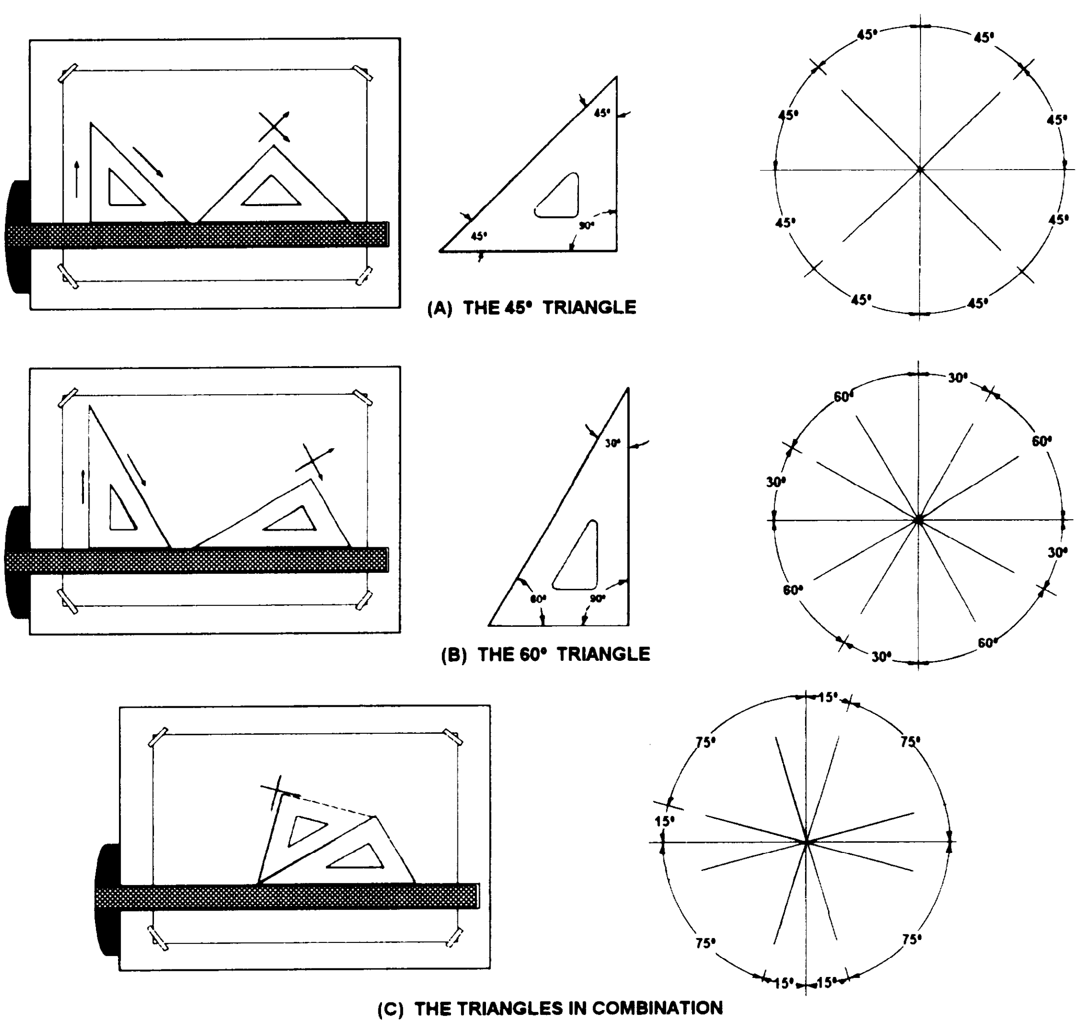


Figure 2-4.—The triangles

microform reproduction. There are two types: fired and extruded. They are similar in material content to plastic fired lead, but they are produced differently. The main drawback with this type of lead is that it does not hold a point well.

PENS

Two types of pens are used to produce ink lines: the ruling pen with adjustable blade and the needle-in-tube type of pen (fig. 2-2). We include the ruling pen here only for information; it has been almost totally replaced by the needle-in-tube type.

The second type and the one in common use today is a technical fountain pen, or needle-in-tube type of pen. It is suitable for drawing both lines and letters.

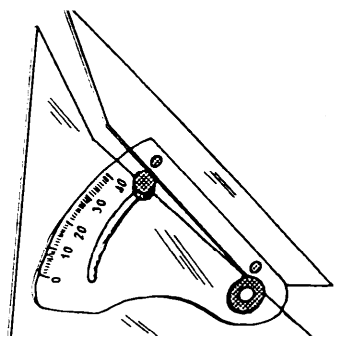


Figure 2-5—Adjustable triangle.

The draftsman uses different interchangeable needle points to produce different line widths. Several types of these pens now offer compass attachments that allow them to be clamped to, or inserted on, a standard compass leg.

DRAWING AIDS

Some of the most common drawing aids are protractors, triangles, and French curves. A protractor (fig. 2-3), is used to measure or lay out angles other than those laid out with common triangles. The common triangles shown in figure 2-4 may be used to measure or lay out the angles they represent, or they may be used in combination to form angles in multiples of 15°. However, you may lay out any angle with an adjustable triangle (fig. 2-5), which replaces the protractor and common triangles.

The French curve (fig. 2-6) is usually used to draw irregular curves with unlike circular areas where the curvature is not constant.

TYPES OF LINES

The lines used for engineering drawings must be clear and dense to ensure good reproduction. When making additions or revisions to existing drawings, be sure the line widths and density match the original work. Figure 2-7 shows the common types of straight

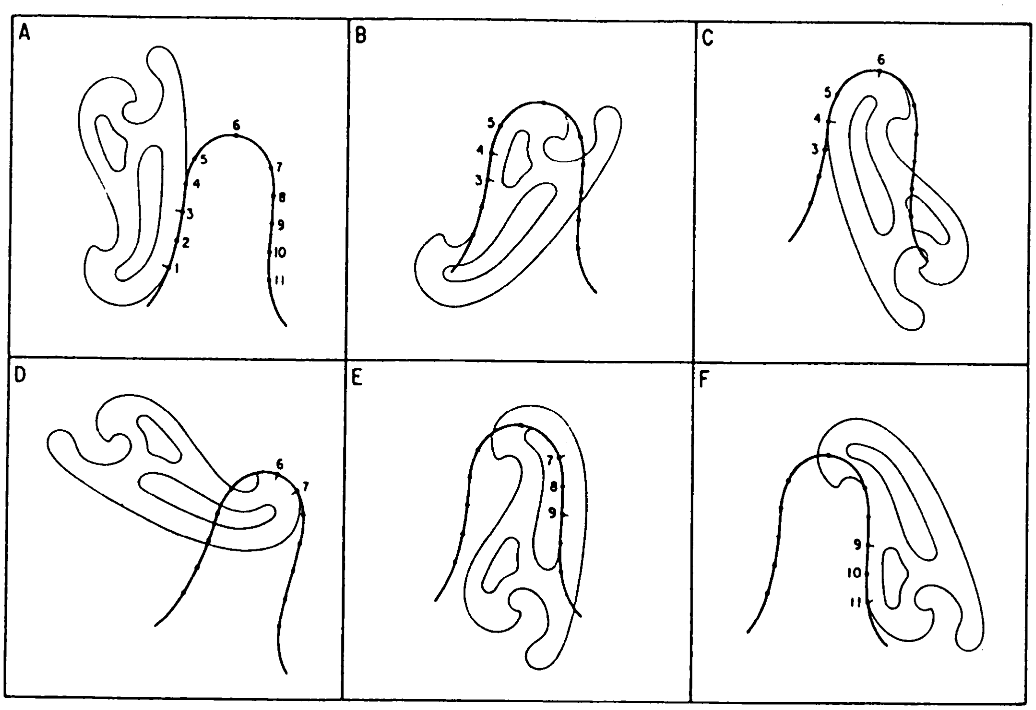


Figure 2-6.—French (irregular) curves.

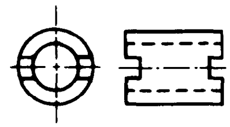
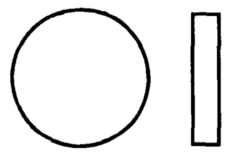
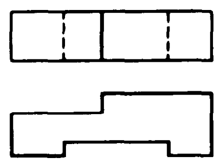
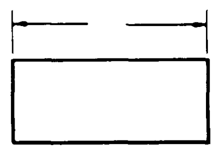
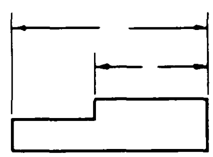
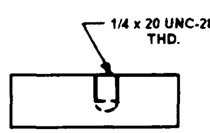
LINE STANDARDS			
NAME	CONVENTION	DESCRIPTION AND APPLICATION	EXAMPLE
CENTER LINES		THIN LINES MADE UP OF LONG AND SHORT DASHES ALTERNATELY SPACED AND CONSISTENT IN LENGTH USED TO INDICATE SYMMETRY ABOUT AN AXIS AND LOCATION OF CENTERS	
VISIBLE LINES		HEAVY UNBROKEN LINES USED TO INDICATE VISIBLE EDGES OF AN OBJECT	
HIDDEN LINES		MEDIUM LINES WITH SHORT EVENLY SPACED DASHES USED TO INDICATE CONCEALED EDGES	
EXTENSION LINES		THIN UNBROKEN LINES USED TO INDICATE EXTENT OF DIMENSIONS	
DIMENSION LINES		THIN LINES TERMINATED WITH ARROW HEADS AT EACH END USED TO INDICATE DISTANCE MEASURED	
LEADER		THIN LINE TERMINATED WITH ARROW-HEAD OR DOT AT ONE END USED TO INDICATE A PART, DIMENSION OR OTHER REFERENCE	

Figure 2-7.—Types of lines.

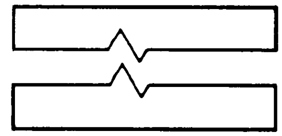
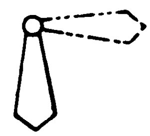
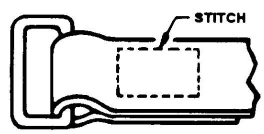
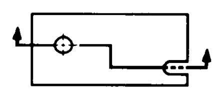
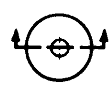
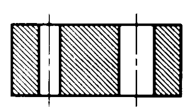
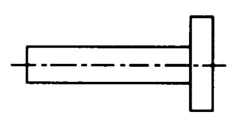
LINE STANDARDS			
NAME	CONVENTION	DESCRIPTION AND APPLICATION	EXAMPLE
BREAK (LONG)		THIN, SOLID RULED LINES WITH FREE-HAND ZIG-ZAGS USED TO REDUCE SIZE OF DRAWING REQUIRED TO DELINEATE OBJECT AND REDUCE DETAIL	
BREAK (SHORT)		THICK, SOLID FREE HAND LINES USED TO INDICATE A SHORT BREAK	
PHANTOM OR DATUM LINE		MEDIUM SERIES OF ONE LONG DASH AND TWO SHORT DASHES EVENLY SPACED ENDING WITH LONG DASH USED TO INDICATE ALTERNATE POSITION OF PARTS, REPEATED DETAIL OR TO INDICATE A DATUM PLANE	
STITCH LINE		MEDIUM LINE OF SHORT DASHES EVENLY SPACED AND LABLED USED TO INDICATE STITCHING OR SEWING	
CUTTING-PLANE LINE		USED TO DESIGNATE WHERE AN IMAGINARY CUTTING TOOK PLACE	
VIEWING-PLANE LINE		USED TO INDICATE DIRECTION OF SIGHT WHEN A PARTIAL VEIW IS USED	
SECTION LINES		USED TO INDICATE THE SURFACE IN THE SECTION VIEW IMAGINED TO HAVE BEEN CUT ALONG THE CUTTING-PLANE LINE	
CHAIN LINE		USED TO INDICATE THAT A SURFACE OR ZONE IS TO RECEIVE ADDITIONAL TREATMENT OR CONSIDERATIONS	

Figure 2-7.—Types of lines—Continued.

lines we will explain in the following paragraphs. In addition, we will explain the use of circles and curved lines at the end of this section.

VISIBLE LINES represent visible edges or contours of objects. Draw visible lines so that the views they outline stand out clearly on the drawing with a definite contrast between these lines and secondary lines.

HIDDEN LINES consist of short, evenly-spaced dashes and are used to show the hidden features of an object (fig. 2-8). You may vary the lengths of the dashes slightly in relation to the size of the drawing. Always begin and end hidden lines with a dash, in contrast with the visible lines from which they start, except when a dash would form a continuation of a visible line. Join dashes at comers, and start arcs with dashes at tangent points. Omit hidden lines when they are not required for the clarity of the drawing.

Although features located behind transparent materials may be visible, you should treat them as concealed features and show them with hidden lines.

CENTER LINES consist of alternating long and short dashes (fig. 2-9). Use them to represent the axis of symmetrical parts and features, bolt circles, and paths of motion. You may vary the long dashes of the center lines in length, depending upon the size of the drawing. Start and end center lines with long dashes and do not let them intersect at the spaces between dashes. Extend them uniformly and distinctly a short distance beyond the object or feature of the drawing unless a longer extension line is required for dimensioning or for some other purpose. Do not terminate them at other lines of the drawing, nor extend them through the space between views. Very short center lines may be unbroken if there is no confusion with other lines.

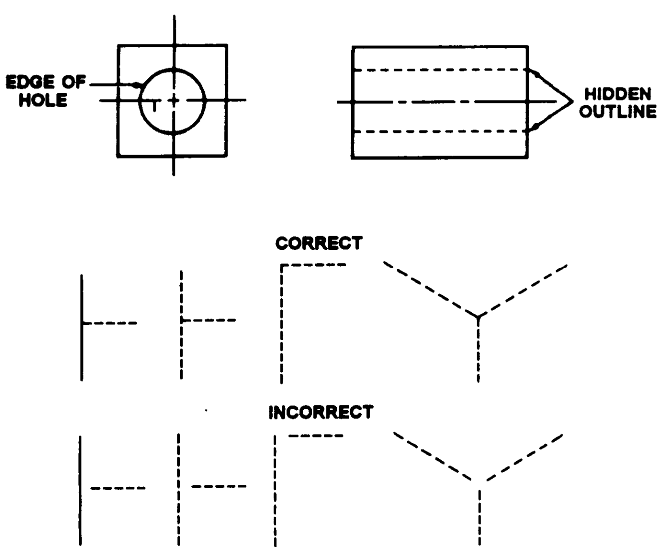


Figure 2-8.—Hidden-line technique.

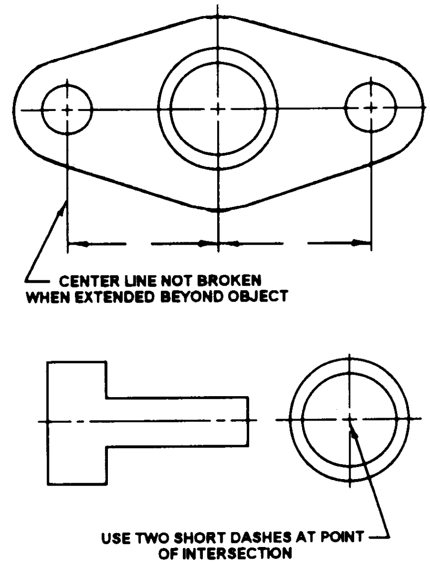


Figure 2-9.—Center-line technique.

SYMMETRY LINES are center lines used as axes of symmetry for partial views. To identify the line of symmetry, draw two thick, short parallel lines at right angles to the center line. Use symmetry lines to represent partially drawn views and partial sections of symmetrical parts. You may extend symmetrical view visible and hidden lines past the symmetrical line if it will improve clarity.

EXTENSION and DIMENSION LINES show the dimensions of a drawing. We will discuss them later in this chapter.

LEADER LINES show the part of a drawing to which a note refers.

BREAK LINES shorten the view of long uniform sections or when you need only a partial view. You may use these lines on both detail and assembly drawings. Use the straight, thin line with freehand zigzags for long breaks, the thick freehand line for short breaks, and the jagged line for wood parts.

You may use the special breaks shown in figure 2-10 for cylindrical and tubular parts and when an end view is not shown; otherwise, use the thick break line.

CUTTING PLANE LINES show the location of cutting planes for sectional views.

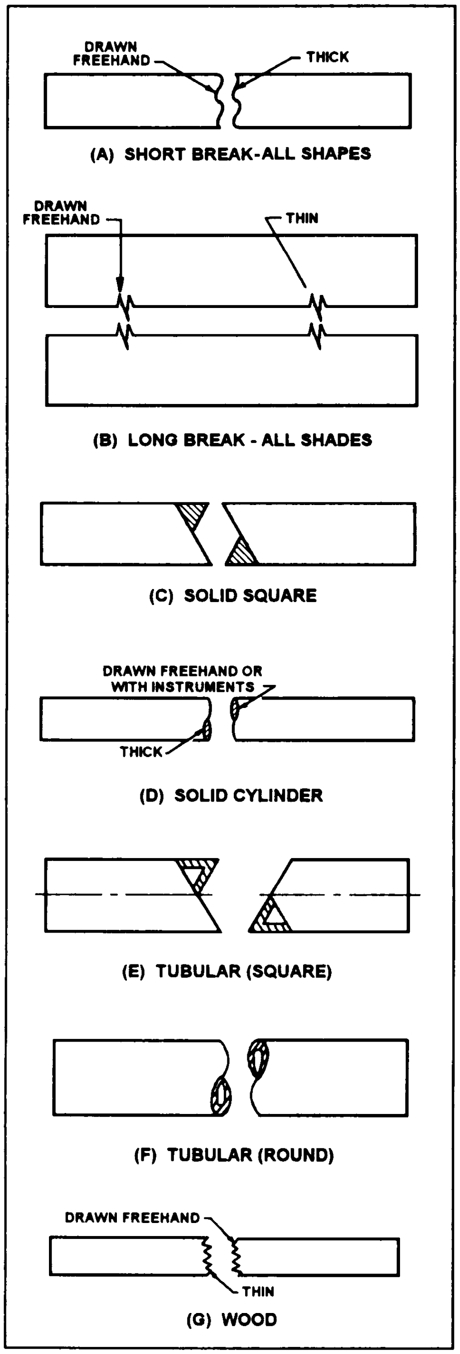


Figure 2-10.—Conventional break lines.

SECTION LINES show surface in the section view imagined to be cut along the cutting plane.

VIEWING-PLANE LINES locate the viewing position for removed partial views.

PHANTOM LINES consist of long dashes separated by pairs of short dashes (fig. 2-11). The long dashes may vary in length, depending on the size of the drawing. Phantom lines show alternate positions of related parts, adjacent positions of related parts, and

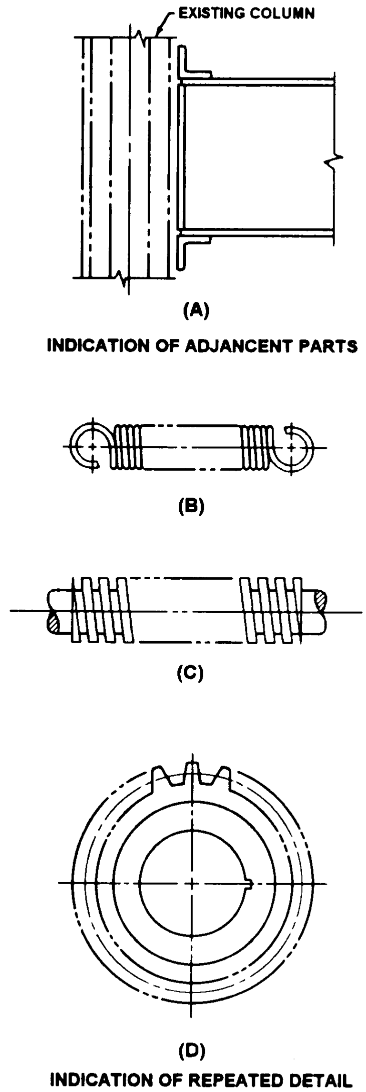


Figure 2-11.—Phantom-line application.

repeated detail. They also may show features such as bosses and lugs to delineate machining stock and blanking developments, piece parts in jigs and fixtures, and mold lines on drawings or formed metal parts. Phantom lines always start and end with long dashes.

STITCH LINES show a sewing and stitching process. Two forms of stitch lines are approved for general use. The first is made of short thin dashes and spaces of equal lengths of approximately 0.016, and the second is made of dots spaced 0.12 inch apart.

CHAIN LINES consist of thick, alternating long and short dashes. These lines show that a surface or surface zone is to receive additional treatment or considerations within limits specified on a drawing.

An ELLIPSE is a plane curve generated by a point moving so that the sum of the distance from any point on the curve to two fixed points, called foci, is a constant (fig. 2-12). Ellipses represent holes on oblique and inclined surfaces.

CIRCLES on drawings most often represent holes or a circular part of an object.

An IRREGULAR CURVE is an unlike circular arc where the radius of curvature is not constant. This curve is usually made with a French curve (fig. 2-6).

An OGEE, or reverse curve, connects two parallel lines or planes of position (fig. 2-13).

BASIC COMPUTER AIDED DRAFTING (CAD)

The process of preparing engineering drawings on a computer is known as computer-aided drafting (CAD), and it is the most significant development to occur recently in this field. It has revolutionized the way we prepare drawings.

The drafting part of a project is often a bottleneck because it takes so much time. Drafter's spend approximately two-thirds of their time "laying lead."

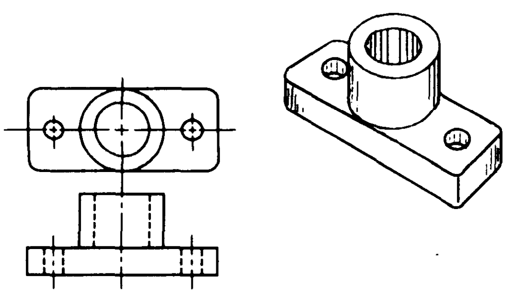


Figure 2-12.—Example of an ellipse.

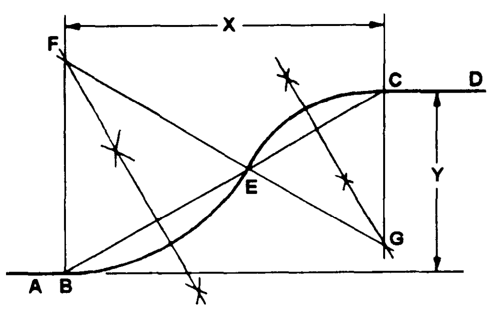


Figure 2-13.—A reverse (ogee) curve connecting two parallel planes.

But on CAD, you can make design changes faster, resulting in a quicker turn-around time.

CAD also can relieve you from many tedious chores such as redrawing. Once you have made a drawing you can store it on a disk. You may then call it up at any time and change it quickly and easily.

It may not be practical to handle all of the drafting workload on a CAD system. While you can do most design and drafting work more quickly on CAD, you still need to use traditional methods for others. For example, you can design certain electronics and construction projects more quickly on a drafting table.

A CAD system by itself cannot create; it is only an additional and more efficient tool. You must use the system to make the drawing; therefore, you must have a good background in design and drafting.

In manual drawing, you must have the skill to draw lines and letters and use equipment such as drafting tables and machines, and drawing aids such as compasses, protractors, triangles, parallel edges, scales, and templates. In CAD, however, you don't need those items. A cathode-ray tube, a central processing unit, a digitizer, and a plotter replace them. Figure 2-14 shows some of these items at a computer work station. We'll explain each of them later in this section.

GENERATING DRAWINGS ON CAD

A CAD computer contains a drafting program that is a set of detailed instructions for the computer. When you bring up the program, the screen displays each function or instruction you must follow to make a drawing.

The CAD programs available to you contain all of the symbols used in mechanical, electrical, or architectural drawing. You will use the keyboard and/or mouse to call up the drafting symbols you need as you need them. Examples are characters, grid patterns, and types of lines. When you get the symbols you want on the screen, you will order the computer to size, rotate, enlarge, or reduce them, and position them on the screen to produce the image you want. You probably will then order the computer to print the final product and store it for later use.

The computer also serves as a filing system for any drawing symbols or completed drawings stored in its memory or on disks. You can call up this information any time and copy it or revise it to produce a different symbol or drawing.

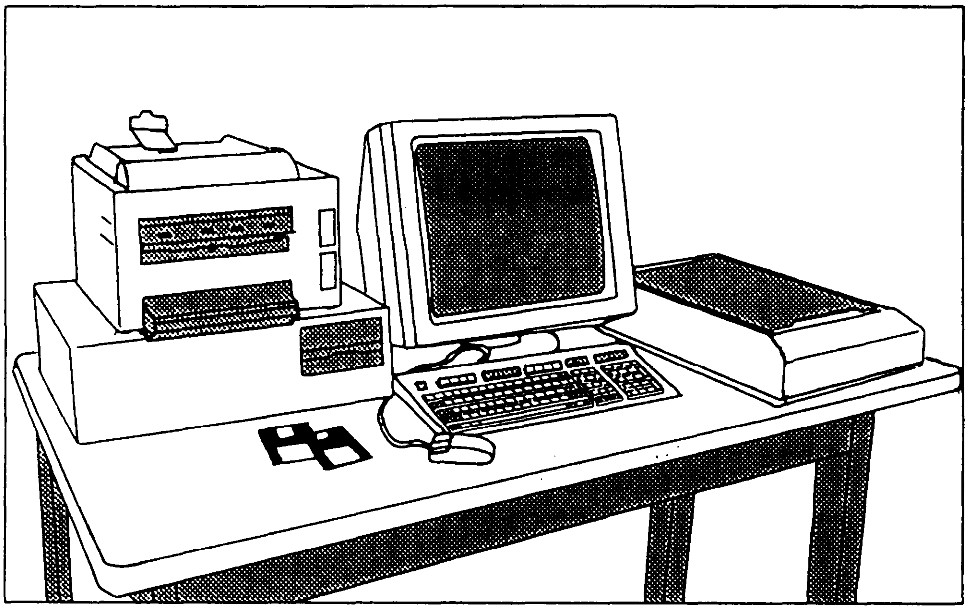


Figure 2-14.—Computer work station.

In the following paragraphs, we will discuss the other parts of a CAD system; the digitizer, plotter, and printer.

The Digitizer

The digitizer tablet is used in conjunction with a CAD program; it allows the draftsman to change from command to command with ease. As an example, you can move from the line draw function to an arc function without using the function keys or menu bar to change modes of operation. Figure 2-15 illustrates a typical digitizer tablet.

The Plotter

A plotter (fig. 2-16) is used mainly to transfer an image or drawing from the computer screen to some

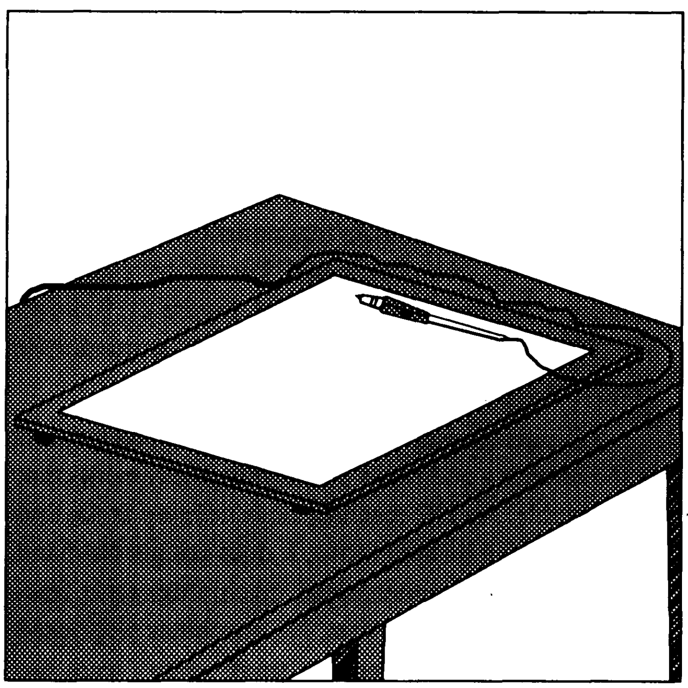


Figure 2-15.—Basic digitizer tablet.

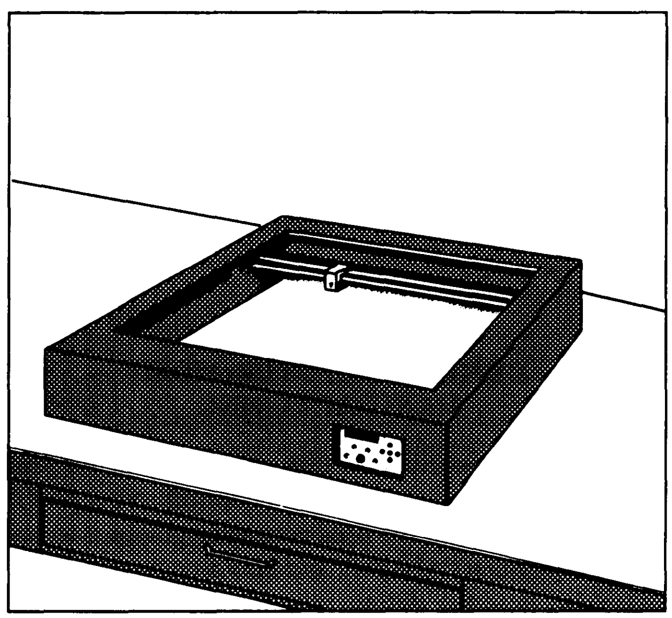


Figure 2-16.—Typical plotter.

form of drawing media. When you have finished producing the drawing on CAD, you will order the computer to send the information to the plotter, which will then reproduce the drawing from the computer screen. A line-type digital plotter is an electro-mechanical graphics output device capable of two-dimensional movement between a pen and drawing media. Because of the digital movement, a plotter is considered a vector device.

You will usually use ink pens in the plotter to produce a permanent copy of a drawing. Some common types are wet ink, felt tip, or liquid ball, and they may be single or multiple colors. These pens will draw on various types of media such as vellum and Mylar. The drawings are high quality, uniform, precise, and expensive. There are faster, lower quality output devices such as the printers discussed in the next section, but most CAD drawings are produced on a plotter.

The Printer

A printer is a computer output device that duplicates the screen display quickly and conveniently. Speed is the primary advantage; it is much faster than plotting. You can copy complex graphic screen displays that include any combination of graphic and nongraphic (text and characters) symbols. The copy, however, does not approach the level of quality produced by the pen plotter. Therefore, it is used primarily to check prints rather than to make a final copy. It is, for example, very useful for a quick preview at various intermediate steps of a design project.

The two types of printers in common use are dot matrix (fig. 2-17) and laser (fig. 2-18). The laser printer offers the better quality and is generally more expensive.

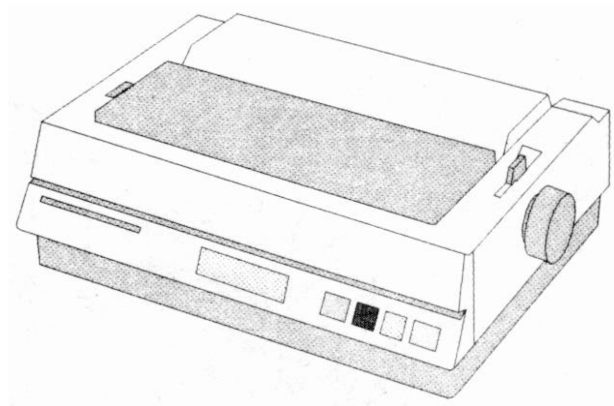


Figure 2-17.—Dot matrix printer.

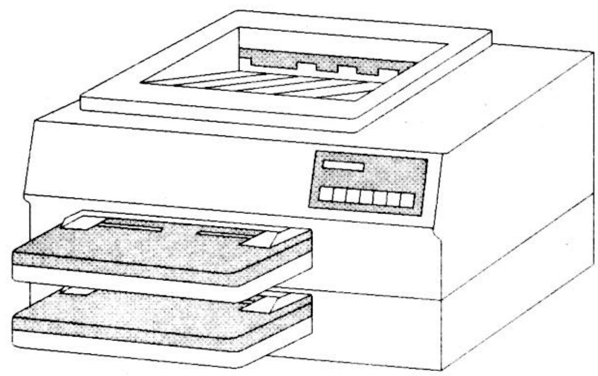


Figure 2-18.—Laser jet printer.

COMPUTER-AIDED DESIGN/COMPUTER-AIDED MANUFACTURING

You read earlier in this chapter how we use computer technology to make blueprints. Now you'll learn how a machinist uses computer graphics to lay out the geometry of a part, and how a computer on the machine uses the design to guide the machine as it makes the part. But first we will give you a brief overview of numerical control (NC) in the field of machining.

NC is the process by which machines are controlled by input media to produce machined parts. The most common input media used in the past were magnetic tape, punched cards, and punched tape. Today, most of the new machines, including all of those at Navy intermediate maintenance activities, are controlled by computers and known as computer numerical control (CNC) systems. Figure 2-19 shows a CNC programming station where a machinist programs a machine to do a given job.

NC machines have many advantages. The greatest is the unerring and rapid positioning movements that are possible. An NC machine does not stop at the end of a cut to plan its next move. It does not get tired and it is capable of uninterrupted machining, error free, hour after hour. In the past, NC machines were used for mass production because small orders were too costly. But CNC allows a qualified machinist to program and produce a single part economically.

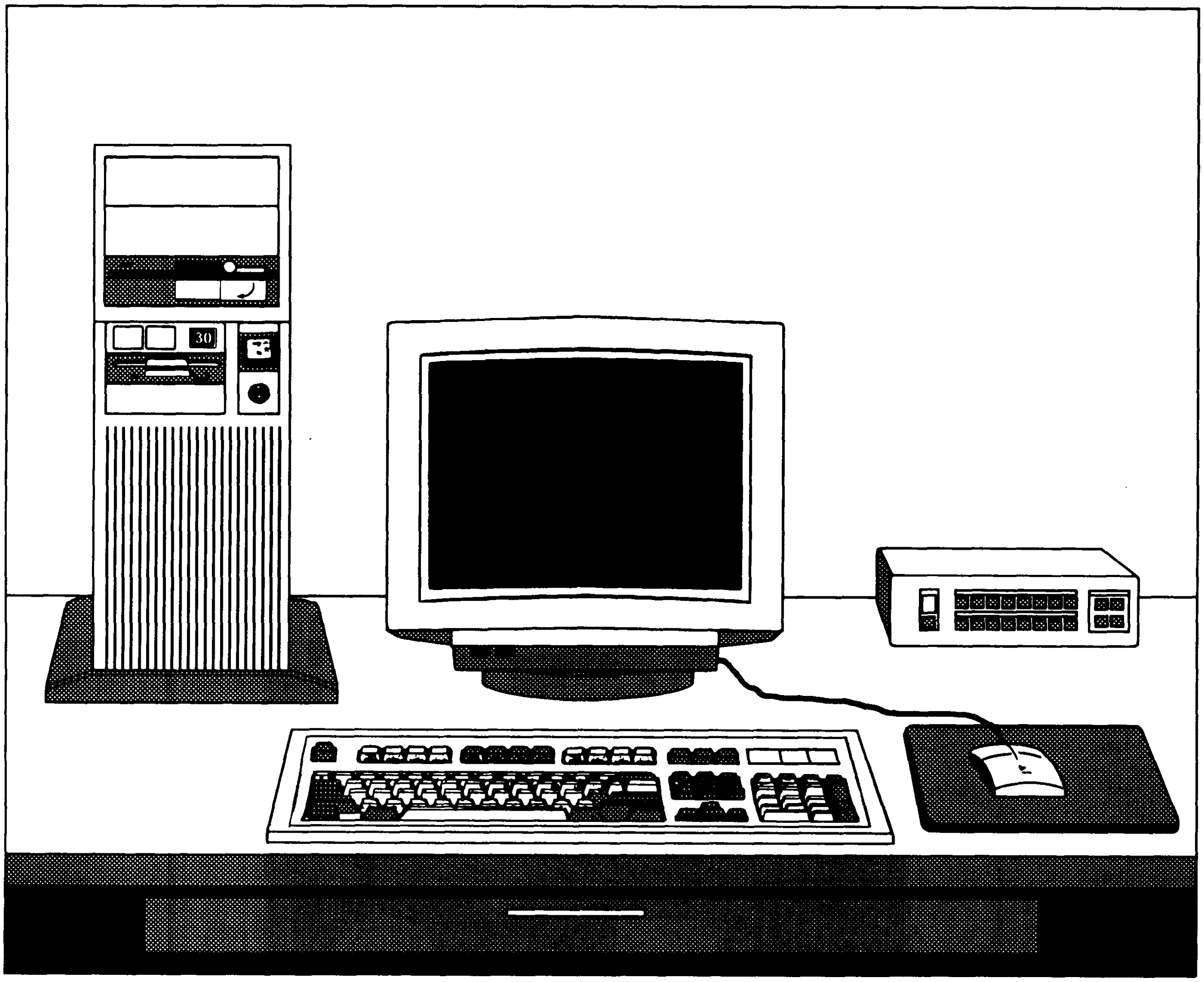


Figure 2-19.—CNC programming station.

In CNC, the machinist begins with a blueprint, other drawing, or sample of the part to be made. Then he or she uses a keyboard, mouse, digitizer, and/or light pen to define the geometry of the part to the computer. The image appears on the computer screen where the machinist edits and proofs the design. When satisfied, the machinist instructs the computer to analyze the geometry of the part and calculate the tool paths that will be required to machine the part. Each tool path is translated into a detailed sequence of the machine axes movement commands the machine needs to produce the part.

The computer-generated instructions can be stored in a central computer's memory, or on a disk, for direct transfer to one or more CNC machine tools that will make the parts. This is known as direct numerical control (DNC). Figure 2-20 shows a

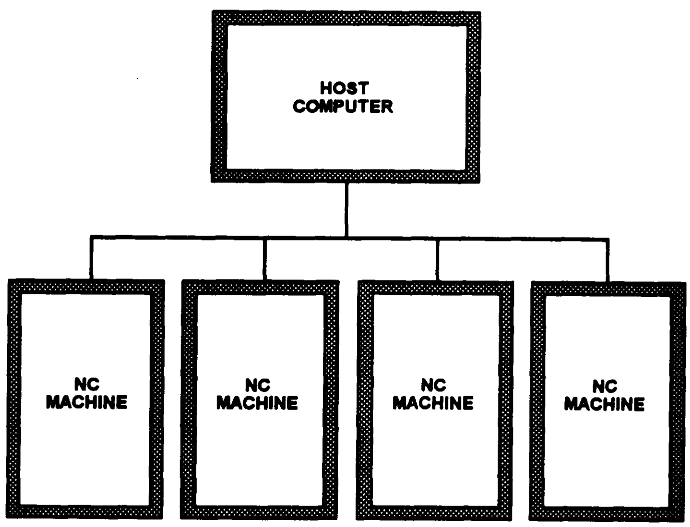


Figure 2-20.—Direct numerical control station.

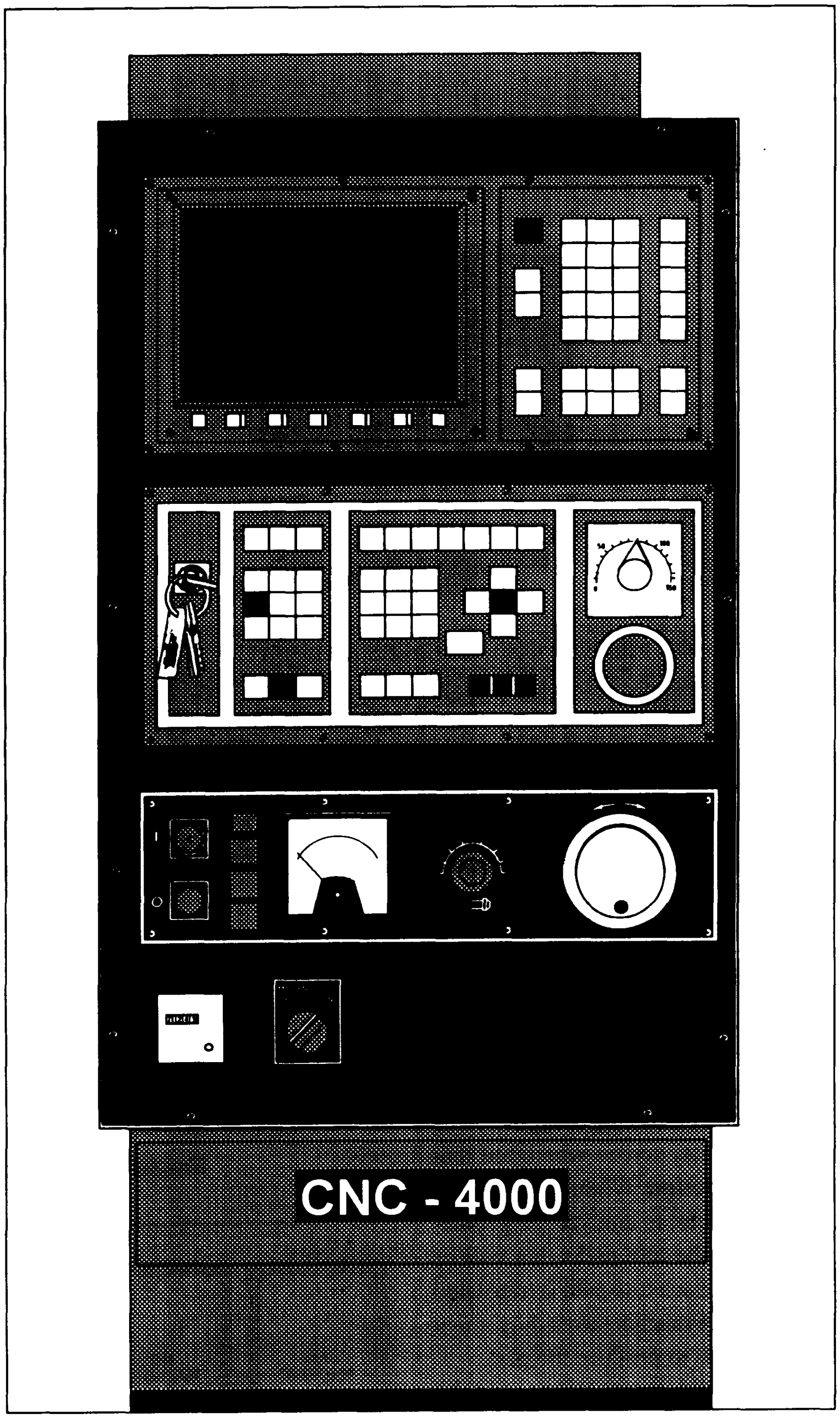


Figure 2-21.—Direct numerical controller.

diagram of a controller station, and figure 2-21 shows a controller.

The system that makes all this possible is known as computer-aided design/computer-aided manufacturing (CAD/CAM). There are several CAD/CAM software programs and they are constantly being upgraded and made more user friendly.

To state it simply, CAD is used to draw the part and to define the tool path, and CAM is used to convert the tool path into codes that the computer on the machine can understand.

We want to emphasize that this is a brief overview of CNC. It is a complicated subject and many books have been written about it. Before you can work with CNC, you will need both formal and on-the-job training. This training will become more available as the Navy expands its use of CNC.